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Dated 26 January 2000

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1. Your reference

REP06150GB

2. Patent a
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3. Full name, address and postcode of the or or each applicant *(underline all surnames)*

Microscience Limited
67-68 Jermyn Street
London
SW1Y 6NY
United Kingdom

Patents ADP number *(if you know it)*

If the applicant is a corporate body, give the country/state of its incorporation

GB 7583685.1

4. Title of the invention

GLUCOSE-6-PHOSPHATE ISOMERASE AND COMPOSITIONS CONTAINING IT

5. Name of your agent *(if you have one)*

GILL JENNINGS & EVERY

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

Broadgate House
7 Eldon Street
London
EC2M 7LH

Patents ADP number *(if you know it)*

745002

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

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Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*

a) any applicant named in part 3 is not an inventor
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YES

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Continuation sheets of this form	
Description	8
Claim(s)	1
Abstract	
Drawing(s)	3 + 3

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Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

11. For the Applicant
Gill Jennings & Every

I/We request the grant of a patent on the basis of this application.

Signature: Gill Jennings & Every

Date: 24 May 1999

12. Name and daytime telephone number of person to contact in the United Kingdom

PERRY, Robert Edward
0171 377 1377

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GLUCOSE-6-PHOSPHATE ISOMERASE AND COMPOSITIONS CONTAINING IT

Field of the Invention

This invention relates to one protein, to vaccines containing it, and to its use in therapy, for immunisation.

Background to the Invention

Group B Streptococcus (GBS), also known as *Streptococcus agalactiae*, is the causative agent of various conditions. In particular, GBS causes:

Early onset neonatal infection.

This infection usually begins *in utero* and causes severe septicaemia and pneumonia in infants, which is lethal if untreated and even with treatment is associated with a 10-20% mortality rate.

Late onset neonatal infection.

This infection occurs in the period shortly after birth until about 3 months of age. It causes a septicaemia, which is complicated by meningitis in 90% of cases. Other focal infections also occur including osteomyelitis, septic arthritis, abscesses and endopthalmitis.

Adult infections.

These appear to be increasingly common and occur most frequently in women who have just delivered a baby, the elderly and the immunocompromised. They are characterised by septicaemia and focal infections including osteomyelitis, septic arthritis, abscesses and endopthalmitis.

Urinary tract infections.

GBS is a cause of urinary tract infections and in pregnancy accounts for about 10% of all infections.

Veterinary infections.

GBS causes chronic mastitis in cows. This, in turn, leads to reduced milk production and is therefore of considerable economic importance.

GBS infections can be treated with antibiotics. However, immunisation is preferable. It is therefore desirable to develop an immunogen that could be used in a therapeutically-effective vaccine.

Summary of the Invention

According to the present invention, a partial GBS gene sequence for the protein Glucose-6-Phosphate Isomerase (GPI) has been found which represents an outer surface protein.

In one aspect of the invention, the use of this protein in a recombinant protein vaccine is described. This vaccine may be administered to females either prior to, or during pregnancy to protect mother and neonate against infection by GBS.

The gene sequence may be first genetically altered to increase the antigenicity of the encoded protein.

Brief Description of the Drawings

The invention will now be described in detail with reference to the accompanying figures, wherein:

Figure 1a shows the partial nucleotide sequence and the deduced amino acid sequence for a 5'/N-terminal situated region of the GBS GPI.

Figure 1b shows the partial nucleotide sequence and the deduced amino acid sequence for a 3'/C-terminal situated region of the GBS GPI.

Figure 2a shows peptide sequence of the GPI obtained from MS/MS peptide sequencing

Figure 2b shows the sequence of oligonucleotides used for PCR amplification of GBS GPI. These were

derived from a consensus region of GPI protein sequences obtained from the SwissProt database.

Description of the Invention

Because of its extracellular or cell surface location, the protein of the present invention may be a suitable candidate for the production of therapeutically-effective vaccines against GBS. The term "therapeutically-effective" is intended to include the prophylactic effect of the vaccines. For example, a recombinant protein may be used, as an antigen for direct administration to an individual. The protein may be isolated directly from GBS or expressed in any suitable expression system, e.g. *Lactococcus lactis*. It is preferably administered with an adjuvant, e.g. alum.

The protein may be a mutant protein in comparison to wild-type protein, a fragment of the protein or a combination of different fragments, provided an effective immune response is generated.

An alternative approach is to use a live attenuated GBS vaccine. This may be produced by deleting the gene that encodes the protein. Preferably, the GBS strain comprises additional virulence gene mutations.

The protein (or fragments thereof) of the present invention may also be used to produce monoclonal and polyclonal antibodies for use in passive immunisation.

In a further embodiment of the invention, the protein or corresponding polynucleotide may be used as a target for screening potentially useful drugs, especially antimicrobials. Suitable drugs may be selected for their ability to bind to the protein to exert their effects. Assays for screening for suitable drugs and which make use of the protein of the invention will be apparent to those skilled in the art.

Although the protein has been described for use in the treatment of individuals, veterinary uses of the protein are also considered to be within the scope of the present invention. In particular, the protein or the vaccines may be used in the treatment of chronic mastitis, especially in cows.

The present invention is described with reference to Group B Streptococcal strain M732. However, all the GBS strains and many other bacterial strains are likely to include related proteins having amino acid sequence homology with the protein of M732. Organisms likely to contain the proteins include, but are not limited to, *S. pneumoniae*, *S. pyogenes*, *S. suis*, *S. milleri*, Group C and Group G *Streptococci* and *Enterococci*. Vaccines to each of these may be developed in the same way as described for GBS.

Preferably, the proteins that may be useful for the production of vaccines have greater than 40% sequence similarity with the protein of M732. More preferably, the proteins have greater than 60% sequence similarity. Most preferably, the proteins have greater than 80% sequence similarity.

The protein of the present invention was identified as follows:

Todd-Hewitt Broth was inoculated with GBS and allowed to grow overnight at 37°C. The cells were harvested by centrifugation and washed with Phosphate Buffered Saline (PBS). The cells were resuspended in an osmotic buffer (20%(w/v) Sucrose, 20mM Tris-HCl pH 7.0, 10mM MgCl2) containing protease inhibitors (1 mM PMSF, 10 µM Iodoeacetic Acid, 10 mM 1,10-Phenanthroline, 1 µM Pepstatin A) and Mutanolysin at a final concentration of 4 Units per microlitre. This was incubated (shaking) at 37°C for 2 hours.

Cells and debris were removed first by high speed centrifugation, then ultra-centrifugation for 1 hour. The resultant supernatant containing cell wall proteins was concentrated under pressure using an ultrafiltration device (10,000 molecular weight cut-off).

The sample was dialysed against ultra high quality water and lyophilised. After resuspension in loading buffer, the proteins were separated by preparative 2-Dimensional-Gel Electrophoresis. Following Electrophoresis an individual spot was chosen for study. The spot was subjected to in-gel tryptic digestion. The resulting peptides were extracted from the gel and purified using microbore RP-HPLC. Fractions were collected every 45 seconds and a portion of these consistent with the regions of UV absorbance were analysed by Delayed Extraction-Matrix Assisted Laser Desorbtion-Time of Flight Mass Spectrometry (DE-MALDI-TOF-MS). Peptides not observed in a blank preparation were then subjected to sequencing using Nanospray-MS/MS

The Peptide sequence obtained is shown in Figure 2a.

This information was sufficient to define the protein from which the peptide originated as Glucose-6-Phospate Isomerase. The sequence of the gene for this protein has been published for various organisms. Using the sequences from *Bacillus subtilis* and *B. stearothermophilus*, two regions of homology between these organisms were identified. These sequences were used to design oligonucleotides for use in a polymerase chain reaction (PCR) to amplify a portion of the GBS GPI gene. The sequences of these oligonucleotides is shown in Figure 2b.

PCR amplification resulted in the production of an (approximately) 1200 base pair fragment, which was cloned into the pCR 2.1-TOPO vector (Invitrogen BV, Netherlands)

according to manufacturers protocol. This plasmid was termed pMS16. The cloned DNA fragment was sequenced. Sequence obtained from the 5' and 3' ends of the cloned fragment were (a) used for database searches (the results of which are shown in Tables 1 and 2) and (b) used to design primers for genomic sequencing of the upstream and downstream region of the original sequence. This resulted in the definition of a defined 5'-translation initiation start signal and a 3'-termination signal.

As shown in Table 1 and 2, homologues to the GBS MS16 gene product can be identified in *Bacillus stearothermophilus, Bacillus subtilis* and *Mycoplasma genitalium*.

In all cases the homologues are the genes for the protein Glucose-6-Phosphate Isomerase (GPI).

The enzyme Glucose-6-Phospate Isomerase catalyses the reaction between Glucose-6-phosphate and Fructose-6-Phosphate in both glycolysis (G6P to F6P) and gluconeogenesis (F6P to G6P). Mutations in the *gpi* gene have been shown to confer purine analogue sensitivity to organisms.

Table 1. Database search results for MS16

Organism	Protein Accession	DNA Accession	Gene Name	% Similarity	% Identity	Alignment Length
Bacillus stearothermophilus	P13375		Glucose-6-Phosphate isomerase A	86	64	120
Bacillus subtilis	P80860	Z93936	Glucose-6-Phosphate isomerase	87	63	120
Bacillus stearothermophilus	P13376		Glucose-6-Phosphate isomerase B	77	56	120
Mycoplasma genitalium	P47357	U39690	Glucose-6-Phosphate isomerase	54	31	121

Table 2. Database search results for MS16 C-terminal

Organism	Protein Accession	DNA Accession	Gene Name	% Similarity	% Identity	Alignment Length
Bacillus stearothermophilus	P13375		Glucose-6-Phosphate isomerase A	78	70	74
Bacillus subtilis	P80860	Z93936	Glucose-6-Phosphate isomerase	74	78	74
Bacillus stearothermophilus	P13376		Glucose-6-Phosphate isomerase B	74	73	74
Mycoplasma genitalium	P47357	U39690	Glucose-6-Phosphate isomerase	55	37	74

CLAIMS

1. A protein comprising an amino acid sequence encoded by the polynucleotide defined as MS16 in Figure 1a or 1b, or a homologue thereof with at least 60% sequence homology.

2. A protein according to claim 1, obtainable from the group B streptococcal strain M732.

3. A protein according to claim 1 or claim 2, wherein MS16 comprises the nucleotides 1-360 of Figure 1a and/or nucleotides 1-261 of Figure 1b.

4. A protein according to any of claims 1 to 3, for use in a method of therapy.

5. A polynucleotide which encodes a protein according to any preceding claim, its complement, or a fragment thereof.

6. The use of a protein according to any of claims 1 to 4, in the manufacture of a vaccine to treat bacterial infection.

7. The use according to claim 6, wherein the infection is a Group B streptococcal infection.

8. The use according to claim 6 or claim 7, wherein the infection is a focal infection.

9. The use according to claim 6 or claim 7, wherein the infection is a urinary tract infection.

10. Use of a product according to any of claims 1 to 5, for screening potential antimicrobial drugs.

11. An antimicrobial drug selected using the products as defined in claim 10.

12. A vaccine comprising a product according to any of claims 1 to 5.

13. A vaccine comprising a microorganism having a virulence gene deletion, wherein the gene codes for a protein according to any of claims 1 to 4.

14. An antibody raised against a protein according to any of claims 1 to 4.

Figure 1a. Partial (towards N-terminal) nucleotide and amino acid sequence of clone MS16

```
        10                  30                  50
GGATGGATGGACCTCCCAGAAAACTATGACAAAGAAGAATTTTCTCGCAT
G  W  M  D  L  P  E  N  Y  D  K  E  E  F  S  R  I

                    70                  90
TCAAAAAGCCGCTGAAAAGATTAAATCAGATAGCGAAGTACTCGTGGTTA
 Q  K  A  A  E  K  I  K  S  D  S  E  V  L  V  V  I

       110                 130                 150
TTGGTATTGGTGGTTCGTACCTTGGTGCAAAAGCAGCAATTGACTTTTTG
  G  I  G  G  S  Y  L  G  A  K  A  A  I  D  F  L

                   170                 190
AATAATCATTTTGCTAATTTGCAAACCGCAGAAGAACGTAAAGCGCCTCA
N  N  H  F  A  N  L  Q  T  A  E  E  R  K  A  P  Q

       210                 230                 250
GATTCTTTATGCTGGAAATTCTATTTCATCTACTTACCTTGCCGATTTAG
 I  L  Y  A  G  N  S  I  S  S  T  Y  L  A  D  L  V

                   270                 290
TTGAATACGTCCAAGATAAAGAATTCTCAGTAAATGTCATTTCAAAATCA
  E  Y  V  Q  D  K  E  F  S  V  N  V  I  S  K  S

       310                 330                 350
GGTACAACAACTGAACCAGCGATTGCTTTCCGTGTATTTAAAGAACTTCT
G  T  T  T  E  P  A  I  A  F  R  V  F  K  E  L  L

AGTTAAAAAG
 V  K  K
```

Figure 1b. Partial (towards C-terminal) nucleotide and deduced amino acid sequence of clone MS16

```
        10                  30                  50
ATTAACCGAAGATTTAGATGGTCTTGGTTATCTTCAAGAAAAGATGTAGA
I  N  R  R  F  R  W  S  W  L  S  S  R  K  D  V  D

                    70                  90
TTTTGTTAATAAAAAAGCAACAGATGGTGTGCTTCTTGCTCATACAGATG
 F  V  N  K  K  A  T  D  G  V  L  L  A  H  T  D  G

       110                 130                 150
GTGGGGTTCCAAATATGTTTGTAACGCTTCCTACACAAGACGCTTACACT
  G  V  P  N  M  F  V  T  L  P  T  Q  D  A  Y  T

                  170                 190
CTTGGTTACACTATTTACTTCTTTGAGTTAGCAATTGGCCTTTCAGGTTA
L  G  Y  T  I  Y  F  F  E  L  A  I  G  L  S  G  Y

       210                 230                 250
TCTTAACTCAGTAAATCCATTTGATCAACCGGGGgTAGAAGCATATAAAC
 L  N  S  V  N  P  F  D  Q  P  G  V  E  A  Y  K  R

GTAATATGTTC
  N  M  F
```

Figure 2a. Generated Peptide Sequence for MS16

SGTTTEPAIAFR

Figure 2b. Oligonucleotide sequences designed from regions of GPI genes showing high homology.

GGWWSWGATTTYYTDGGWTGG

WCCWGGTTTWCCHARWGCRAACAT

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Gill Jennings & Every